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# An Innovative Magnetic Charging Chute To Improve Productivity Of Sinter Machine at Rourkela Steel Plant

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**Abstract**

Sintering is a process in sinter machine for agglomeration of iron ore and other raw material fines into a compact porous mass, i.e., sinter, used in Blast Furnaces as an iron bearing input charge material for hot metal production. 'Permeability' of sinter-bed on sinter machine i.e., the porosity in sinter-bed of charged materials, facilitates atmospheric air passes from the top to bottom across the depth of sinter-bed, when suction created from the bottom of the bed, for efficient heat carry over from top to bottom of the bed for complete burning of charged materials for effective sintering process controls the productivity of the sinter machine. The level of 'permeability' in sinter-bed is depending upon the effectiveness of 'charging chute' in size-wise 'segregation' of charge materials across the depth in sinter-bed, achieved due to differences in the sliding velocities of particles during charging into the moving sinter-bed. The permeability achieved by the earlier conventional 'charging chute' was limited due to its design and positional constraints in sinter machine. Improving the productivity of sinter machine, through increased permeability of sinter bed is successfully achieved through implementation of an innovatively designed and developed, "Magnetic Charging Chute" at Sinter Plant no. 2 of Rourkela Steel Plant. The induced magnetic force on the charged materials while the charge materials dropping down through the charge chute has improved the permeability of sinter bed through an unique method of segregating the para-magnetic materials and the finer materials of the charge materials to top layer of sinter bed along with improved size-wise segregation of charge materials. This has increased the productivity of the sinter machine by 3% and also reduced the solid fuel consumption i.e., coke breeze in input charge materials by 1 kg/t of sinter.


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Keywords: Sintering; Segregation; Permeability; Charging chute; Bulk-density; Productivity

## 1. Introduction

It is well known that, productivity of a sinter machine is greatly depends upon "permeability" of the sinter bed i.e. porosity of sinter bed, which facilitates atmospheric air flow across depth of bed and "yield" [1]. Permeability is greatly influenced by the size-wise 'segregation' of charge particles across the depth of sinter bed, achieved by a 'charging chute', provided below the raw mix hopper of the sinter machine. In an efficient permeable sinter-bed, the coarser material forms the bottom layer and the finer material forms the top layer of the sinter-bed. This facilitates smooth air flow across the depth of sinter-bed from top to bottom, which carries necessary heat along with from the top, for efficient burning of charged materials across the depth of bed for converting the charge materials into useful 'sinter'. For an efficient permeable sinter bed, any compression of sinter bed caused by the gravitational forces or external densification of the sinter mix due to dropping impact force during charging for formation


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of the sinter bed should also be avoided [1]. However the earlier conventional charging chute has limitations in both improving the size segregation of charge materials and limiting the dropping impact force on sinter bed formation due to its design and positional limitations in sinter machine. In addition to the above limitations, in conventional sintering process, 'heat deficiency' at top portion of sinter bed, due insufficient presence of fuel materials at top[2], causes generations of weak sinter fines leading to reduction in 'yield' of sinter production.

To counter the above challenges of the earlier conventional 'charging chute' of a sintering machine in improving the productivity and yield of sinter machine, various designs of charging chutes were investigated. Based on the fact that the sintering raw material contains a large amount of para-magnetic materials such as mill scales and return sinter fines, the authors investigated the effect of magnetism in a charging chute. The basic efforts were to increase the porosity of sinter bed and hence permeability of the bed by allowing soft charging of materials, which is achieved by inducing magnetic dragging force to all the materials during charging and to improve the yield by providing additional heat at the top by segregating paramagnetic materials to the top of sinter bed. On successful establishment at laboratory experiment, an innovative 'magnetic charging chute' was designed, developed and implemented in sinter plant no. 2 of Rourkela Steel Plant. This paper describes in detail about the concept, development and implementation of 'magnetic charging chute' at Rourkela Steel Plant.

**2. Conventional sinter-mix charging system**

Charging of sinter-mix / charge materials / raw materials of sintering, on continuously forward travelling pallet to form a sinter bed assumes great importance to improve the size-wise segregation of charge materials in sinter bed for efficient sinter bed permeability[1], which greatly affects the productivity of sinter machine. The charge materials from the raw-mix hopper are charged into forward moving pallets by a drum feeder through statically positioned charging chute. For effective permeability of sinter bed any compression caused by gravitational forces or external densification of the sinter mix during the formation of sinter bed should be avoided. From the days of development of this technology various types of systems have been adopted of which drum feeder have been accepted as standard charging system for sinter mix. Schematic diagram of conventional charging system is shown in Fig. 1a.

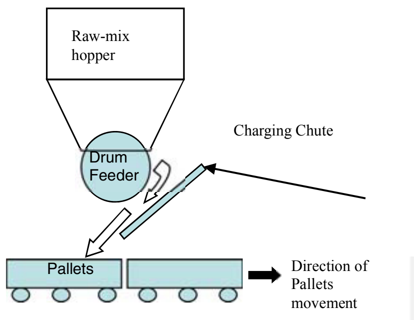


Fig. 1a: Conventional Charging System

During charging of materials through the chute, it has been observed that the particles move in a system where each particle is mechanically locked between the proceeding & succeeding particle and there is absolutely no free movement of any individual particle. This sliding (rolling) movement through sufficient distance i.e., rolling length on the charging chute ensures vertical size-wise segregation of particles in sinter bed under gravity, while angle of charging chute controls bed permeability and sinter bed density [2]. The concept of rolling length is explained in Fig. 1b. It is well known that, decrease in dropping velocity of charge materials increases void fraction in bed, hence any reduction in dropping velocity in addition to normal friction force on sliding particles increase bed permeability significantly. The level of segregation of charge materials is depending upon the 'rolling length' of the charge materials on the surface of the charging chute [2]. That is, the more the rolling length, the higher the size-segregation. However increasing the rolling length of the conventional charging chute is a bottleneck due to its design and positional limitations. The dropping speed of the charge materials while sliding through the charging chute into pallets affects the bulk density of the sinter-bed. That is, the more dropping velocity of charge material is the poorer of permeability of sinter bed. However the conventional 'charging chute' could not control the density of the sinter-bed for better permeability as it does not have any control over the dropping velocity of charge materials while charging into sinter bed.

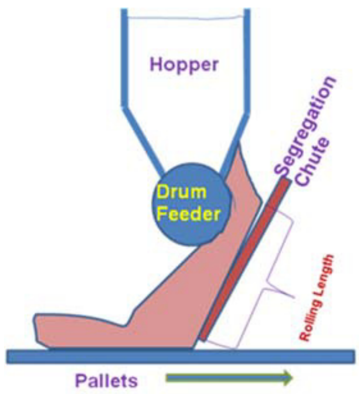


Fig. 1 b: The concept of rolling length

It is well known that improving the performance of the charging chute is the most appropriate option that would provide maximum improvement in productivity of the sinter machine. It is also an attractive option due to its low cost of investment, simple design modification and short period of implementation.

**3. Concept of magnetic charging chute**

The concept establishes that if a magnetic field is impressed on charge materials of sinter while travelling through the charging chute, their dropping velocity shall greatly be reduced. Due to the induced magnetic field, the frictional resistance of charge materials increases by an amount equal to the product of the magnetic force and the coefficient of friction. This creates a magnetic braking force on the charge materials while dropping/sliding down through the charging chute and hence significantly reduce their dropping velocity. Due to the induced magnetic braking force, the charge materials are charged onto the moving pallets slowly and softly. The soft loading of charge materials helps in increasing the bed permeability of the sinter bed, due to decreased compaction of the bed. The reduced dropping velocity has also leads to increase in the size-wise segregation of charge materials in sinter bed due to induced greater difference in their dropping velocities among the size fractions of the charge materials. The concept of magnetic chute is depicted in Fig. 2. Further to the above technological benefits, the magnetic charging chute has also helps in unique segregation of para-magnetic materials such as 'mill-scales' and 'return-sinter fines' to the top portion of the sinter bed by greatly affecting their dropping velocities compared to non-magnetic materials. The unique segregation of mill-scales and return-sinter, which are highly heat generative at low temperature melting capability, to top of sinter bed provides additional heat at top, which helps in increasing the yield by accelerating the rate of pore coalescence. This helps in reducing the consumption of solid fuel i.e., 'coke breeze' in raw material of sintering, or otherwise added further to compensate the heat deficiency at the top, normally happens in conventional sintering. The effect of magnetic field on dropping velocity of charge material and bulk density of sinter bed is depicted in Fig. 3.

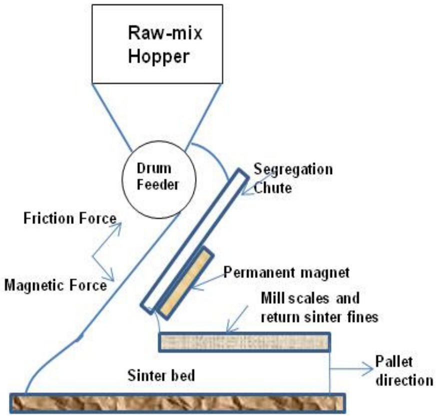


Fig. 2: Concept of magnetic charging chute

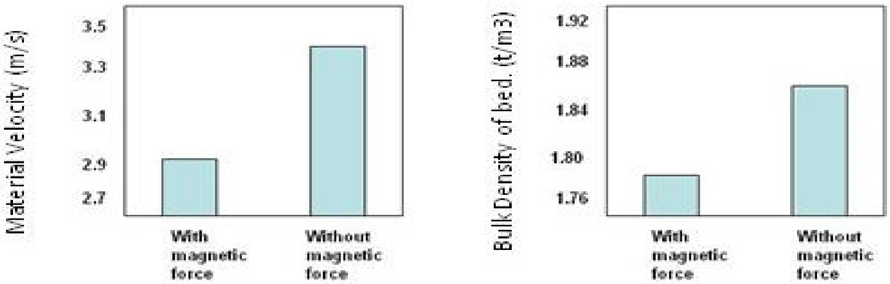


Fig. 3 : Effect of the magnetic field on charge material velocity and charged bed density

**4. Estimation of magnetic strength on chute**

Stainless Steel plate of 16 mm thick, 1000 mm width and 1200 mm length has been fabricated with structural support as a charging chute. The chute was kept at an inclination angle of around 55o, simulating the actual plant conditions. A provision to change the inclination angle of the chute is provided through manual adjusting screws. Ferrite type permanent magnets of different thickness are used in the trials to find the optimum strength. The air gap between the magnet and chute is adjustable manually to vary the magnetic flux density on the surface of the chute from 0 gauss and 1200 gauss. The following were observed through the laboratory trials carried out on sinter raw materials collected from Rourkela Steel Plant:

- The maximum magnetic strength is achieved with 1' size magnet is about 1200 gauss
- There is no magnetic effect on iron ore fines.
- The magnetic effect is higher on dry sinter mix compared to wet sinter mix
- The magnetic braking force on the sinter mix increases with magnetic strength.
- The magnetic effect is high at 1200 gauss and low at 700 gauss.

According to Yajima [3], the magnetic force acting on a particle can be expressed by the following equation (1), which was used to calculate the theoretical estimation of magnetic force acting on various sintering raw materials for validating the values achieved through physical simulations tests carried out at the laboratory. Configuration of individual magnetic pieces in assembly of magnetic plate for achieving optimum polarity suitable for charging chute applications is another important parameter, which has been established through laboratory trials. Various combinations of polarity arrangements of magnetic pieces were tried to find an optimum formation of magnetic pieces, which can facilitates smooth material flow downwards through the chute surface.

$$FM = 4/3\Pi r^3 \rho \varkappa H dH/dx \quad (1)$$

$$H = A \exp(-bx) \quad (2)$$

Where,
FM = magnetic force (dyne)
r = particle radius (cm)
ρ = density ($gm/cm^2$)
ϰ = magnetic susceptibility (-)
x = distance form magnet (cm)

**5. Magnetic charging chute**

A magnetic plate of ferrite type permanent magnet of suitable size and magnetic strength was fabricated by assembling small pieces of magnets in suitable polarity configuration. The magnetic plate was installed on the top of the mother/base plate of the chute at its bottom portion by suitable fasteners. The magnetic plate was fitted on top surface of the mild steel base plate due to unavoidable site constraints at backside of the chute. On the top of magnetic plate, a liner plate made of SS-304 of suitable dimensions is provided to protect the magnets against direct materials contact of charge materials to improve the life of magnets. Stainless steel was preferred for liner plate, as stainless steel being a nonmagnetic, does not make inference in the magnetic field. The position of the stainless steel liner plate can be adjusted according to the bed height by a mechanical lifting and lowering mechanism provided through turnbuckle–tie rod mechanism. However the gap between the magnetic plate and the liner plate is kept constant to maintain an optimum magnetic field throughout the process as the quality of the raw materials does not change significantly for a particular plant. The schematic arrangement of magnetic charging chute is shown in Fig. 4 and the photograph of the magnetic plate used in actual application in Rourkela Steel Plant is shown in Fig 5.

Fig. 5: Photographic view of the magnetic chute

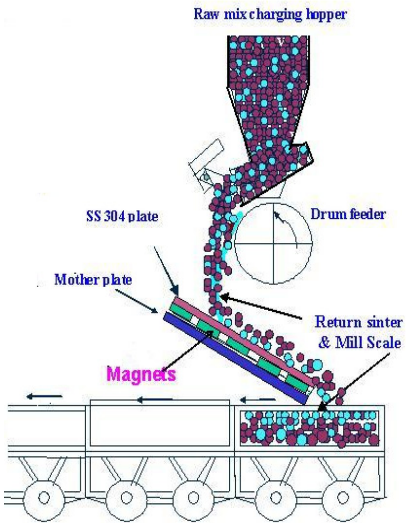


Fig. 4: Schematic arrangement of magnetic chute based charging system

## 6. Results and Discussion

### *6.1. Effect on air filtration velocity*

Using a diverging hood and vane type anemometer, air filtration velocities across the sinter bed were measured on top of the bed before and after the implementation of the magnetic charging chute. The average air filtration velocity across the sinter bed has improved by 20% from the earlier level of 0.25 m/s to 0.30 m/s.

It is also observed that the air filtration velocity is more uniform across the sinter bed due to improved bed permeability. The effect of magnetic field on air filtration velocity measured across the sinter bed before and after implementation of the magnetic chute is shown in Fig. 6.

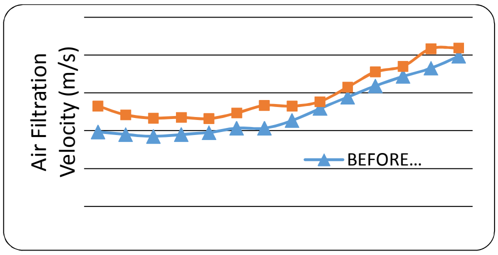


Fig. 6: Air filtration velocity across the sinter bed

### *6.2. Effect on sinter machine speed*

The average sinter machine speed has improved by 5 % from the level of 2.2 m/min with bed height of 600 mm after the introduction of magnetic charging chute, due to increase in void fractions on sinter bed and segregation of charge particles. The increase in machine speed shall lead to improvement in productivity of the sinter machine by around 3 %. The effect of magnetic chute on sinter machine speed is shown in Fig. 7.

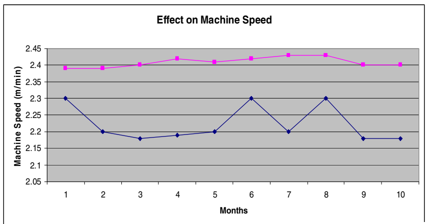


Fig. 7: Effect on sinter machine speed

### *6.3. Effect on solid fuel consumption*

The magnetic force induced by the magnetic charging chute, helps in unique segregation of mill-scales and return-sinter fines, which are highly heat generative and low temperature melting capabilities to top portion of sinter-bed. This has helped in reduction in average solid-fuel consumption by 1 Kg/ts from the level of 65 kg/t to 64 kg/t.

### *6.4. Other positive effects of magnetic chute*

The Strength of Sinter (Tumbler Index) has increased by 6 % from the earlier value of 60. Generation of -5 mm of return-sinter fines has decreased by 3% from the earlier level of 18.2 %. The yield of sinter machine is increased by 1% due to increased pore coalescence in the top layer.

## 7. Conclusion

The Magnetic Charging Chute was designed and developed with a objective of improving sintering productivity and was implemented at Sinter Plant # 2 of Rourkela Steel Plant. It was established that the magnetic braking force on charge materials has significantly reduces their dropping velocity, facilitating soft loading of charge material on sinter bed causing improved porosity i.e., permeability of sinter bed. Additionally it has improved the segregation of paramagnetic materials to top of the sinter bed, causing additional heat availability at the top and hence improvement in yield of sinter. After its significant period of utilization in sinter plant, it was confirmed that the unit consumption of coke breeze has been reduced by 1 kg / t of sinter. As this device uses a ferrite type permanent magnet, it does not require any power supply and it is totally safe of operation and maintenance free.

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